ELECTRICAL SAFETY TRAINING MANUAL
NATIONAL HIGH MAGNETIC FIELD LABORATORY
AT
FLORIDA STATE UNIVERSITY

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INTRODUCTION

Electrical hazards exist in many areas of the National High Magnetic Field Laboratory (NHMFL). Fortunately, the electrical hazards at NHMFL are managed through equipment design, proper equipment maintenance, and work practices. However, equipment may fail and proper operating procedures or manufacturer's guidelines may not be strictly followed. These conditions may present electrical hazards.

The hazards associated with electricity can damage or destroy equipment and cause fires. More importantly, electrical shock can burn and kill. The Bureau of Labor Statistics reports that in 1992, 5.5 % of all fatal accidents at the workplace were due to contact with electric current. What makes these statistics more tragic is that, for the most part, these fatalities could have been easily avoided.

NHMFL personnel work with electricity in a variety of ways. Electrician's and Control Room Operator's work may involve *direct* contact or contact by means of tools with energized equipment. Others, such as laboratory staff and administrative staff work with electricity *indirectly* when working with laboratory equipment.

This training manual is designed to provide those employees who work *indirectly* with electricity general knowledge related to preventing accidents from electrical hazards. The manual is presented in the following sections:

- **Objectives** - A list of the learning objectives for this training.

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- **Regulations and Standards** - Applicable federal regulations and accepted standards.
- **Fundamentals of Electricity** - An introduction to how electricity acts and causes injury. This section also provides some resolution about some commonly held falsehoods about electricity.
- **Hazards of Electricity** - A review of common hazards associated with electricity.
- **Hazardous Locations and Equipment at the NHMFL** - Review of the major locations and equipment at NHMFL which present electrical hazards.
- **Minimizing Electrical Hazards** - Protective measures when working with or around electricity.
- **Summary**
- **Glossary of Terms**

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COURSE OBJECTIVES

This course will provide basic information concerning electrical safety. As a result of this training, the following objectives will be met:

- The student will be able to identify the sources of applicable electrical regulations and standards.
- The student will demonstrate a understanding of the principles of electricity and associated terminology.
- The student will identify the hazards associated with electricity.
- The student will be able to describe the effects of electric shock on the body.
- The student will be able to identify high voltage and restricted locations. The student will be able to determine who is qualified to be in these areas.
- The student will describe measures for minimizing electric hazards.

WHAT ARE THE REGULATIONS AND STANDARDS?

OSHA's electrical standards address the concern that electricity has long been recognized as a serious workplace hazard, exposing employees to such dangers as electric shock, electrocution, fires, and explosions. The objective of the standards is to minimize such potential hazards by specifying *design* characteristics of safety in use of electrical equipment and systems.

OSHA's electrical standards were carefully developed to cover only those parts of any electrical system that an employee would normally use or contact. The exposed and/or operating elements of an electrical installation - lighting equipment, motors, machines, appliances, switches, controls, enclosures, etc. - must be so constructed and installed as to minimize electrical dangers to people in any workplace.

OSHA's electrical standards include:

- 29 CFR 1910 Electrical Subpart S, 1994 revision
- 29 CFR 1910.147 - Control of Hazardous Energy (Lockout/tagout)
- 29 CFR 1910.137 - Personal Protective Equipment Standard, Electrical Protective Equipment.

The OSHA electrical standards were based on the National Fire Protection Association's standard NFPA 70E, *Electrical Safety Requirements for Employee Workplaces*, and the NFPA 70 Committee derived Part I of their document from the 1978 edition of the *National*

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Electrical Code (NEC). The standards extracted from the NEC were those considered to most directly apply to employee safety and least likely to change with each new edition of the NEC.

OSHA's electrical standards are performance oriented; therefore, they may contain few direct references to the NEC. However, the NEC contains specific information as to how the required performance can be obtained.

In addition, the following standards and guidelines apply to electric installations:

- The American National Standards Institute (ANSI) publishes standards for tool design and safeguarding, including the Safety Standard for Stationary and Fixed Electric Tools. ANSI/UL 987.
- National Electric Manufacturer's Association (NEMA) Standards.
- American Society for Testing Materials (ASTM) - publishes specifications for electrical protective equipment.
- Underwriters Laboratories (UL) - Electrical Equipment Approval.

In order to work safely with electricity, a basic understanding of electricity and electrical action is necessary. This section provides a summary of these important concepts.

WHAT IS ELECTRICITY?

The American Heritage Dictionary defines electricity as "The physical phenomena arising from the behavior of electrons and protons that is caused by the attraction of particles with opposite charges and the repulsion of particles with the same charge." But what does this *really* mean?

Most everyone has heard the terms: volts, amps, watts, ohms, and kilowatt-hour. However, the meanings of these terms may seem vague. This section provides an overview of electricity in simple terms.

UNDERSTANDING ELECTRICITY IN SIMPLE TERMS

An easy way to understand electricity is to think of it like water flowing through a pipe. In order to have a flow of water three things must occur. First, there must be a source of water, like a reservoir. Second, the water must be transported on or in something... like a pipe. Third, there must be a source of pressure, like a water pump, to make the water flow. Electricity is similar! Like the water reservoir, the **source** of electricity is a battery, generator, or power station. A "conductor" is a term used for anything which can **transport** electricity, like a wire, the air, and even the human body. An electric generator provides the "**pressure**" to transport electric ***current*** in a conductor.

NOTES:

Current = Flow
Voltage = Pressure
Resistance = Friction

NOTES:

***Electron** - a type of elementary particle that, along with protons and neutrons, make up atoms and molecules. Electrons have a negative charge.*

American Wire Gauge (AWG) Wire Sizes and Common Uses

AWG Wire Size	Use
4	Power Lines
14	Residential Circuits
22	Telephone Lines

Some materials conduct electricity better than others. For example, copper wires conduct better than aluminum wires.

What is "Current?"

Simply put, current is the *flow* of electric charge, or electrons. Just as water flows in a pipe, charged particles flow in a conductor. For example, we use the term "flow" to describe how much water flows through a pipe in a given amount of time. In electrical terms, "current" describes how many electrons flow through a conductor in a given amount of time. Current is measured in amps.

How else is electricity related to water flow?

In many ways, but we'll discuss only three more. We mentioned water pressure previously. In electrical terms, "voltage" is the pressure which drives charged particles to move.

Another important concept is "resistance". Inside a water pipe, friction occurs between the walls of the pipe and the water. This causes a drop in water pressure along the length of the pipe. Resistance is like friction which causes a drop in voltage..

The water flow at a given pressure is controlled largely by the *pipe size.* A larger pipe will allow more gallons per minute of water to flow than a smaller pipe at a given pressure. Similarly, larger wires allow more current to flow at a given voltage. Wire sizes are determined by their American Wire Gauge (AWG) numbers. The larger the number, the smaller the diameter of the wire. In general, larger wires have less resistance than smaller wires.

OK, so electricity is exactly like water flow?

Well, not exactly. Our water flow analogy only applies to direct current (DC) electric circuits. Like water, direct current flows in one direction. Alternating current flows back and forth at a specific rate, or frequency. There is no direct analogy between AC current and water flow.

We've been mentioning the term "Electric Circuit".... What's that?

An electric circuit is an unbroken path along which an electric current may flow. A simple circuit consists of a voltage source, such as a battery or a generator, whose terminals are connected to those of a circuit element, such as a resistor, through which current can flow. The human body can be part of an electric circuit. We'll discuss this later in the Hazards of Electricity Section.

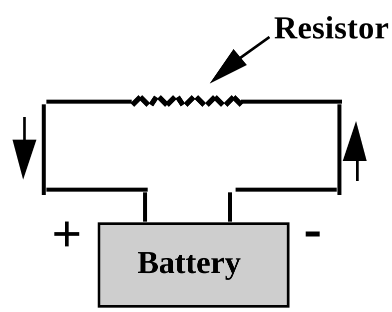
Ohm's Law

Current flows in an electric circuit in accordance with several definite laws. The basic law of current flow is Ohm's law. Ohm's law states that the amount of current flowing in a circuit made up of only resistors is related to the voltage on the circuit and the total resistance of the circuit. The law is usually expressed by the formula V=IR, where I is the current in amperes, V is voltage (in volts), and R is the resistance in ohms.

Ohm's law applies to all electric circuits for both DC and AC, but additional principles must be employed to analyze complex circuits and for AC circuits also involving other components like "inductors" and "capacitors".

N O T E S :

A resistor is a circuit element placed in an electric circuit which causes a drop in voltage or current. Other circuit elements include transistors, capacitors, and transformers (please see the Glossary for definitions of these terms).



Simple Electric Circuit

Ohm's Law is named for its discoverer, the German physicist George Ohm.
Ohm's Law: V=IR

ELECTRICAL CURRENT AND THE HUMAN BODY

The five primary hazards associated with electricity and its use are:

1. **Shock**. Electric shock occurs when the human body becomes part of a path through which electrons can flow (i.e., *the circuit*). The resulting effect on the body can be either direct or indirect:

   - Direct. Injury or death can occur whenever electric current flows through the human body. Currents of less than 30 milliamps (mA) can result in death.

   - Indirect. Although the electric current through the human body may be well below the values required to cause noticeable injury, human reaction can result in falls from ladders or scaffolds, or movement into operating machinery. Such reaction can result in serious injury or death.

There are three basic ways which shock occurs:

- A person comes in contact with both wires of an electric circuit.

- A person comes in contact with a wire from an electric circuit and the ground source.

- A person comes in contact with a ground source and a metal part that is in contact with a wire from an electric circuit.

N O T E S :

Shock - Occurs when electric current flows through the body.

A milliamp (mA) is 1/1000 of an AMP.

Ground - A ground is a connection in an electrical circuit that leads to the earth, or to a large conducting object that is at zero volts with respect to the rest of the circuit. (please see the Glossary for a more detailed discussion)

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2. **Burns**. Burns can result when a person touches electrical wiring or equipment that is improperly used or maintained. Typically, such burn injuries occur on the hands.

3. **Arc-Blast**. Arc-blasts occur from high-amperage currents arcing through air. This abnormal current flow (arc-blast) is initiated by contact between two energized points. This contact can be caused by persons who have an accident while working on energized components, or by equipment failure due to fatigue or abuse. Temperatures as high as 35,000^{o}F have been recorded in arc-blast research. The three primary hazards associated with an arc-blast are:

   - **Thermal Radiation**. In most cases, the radiated thermal energy is only part of the total energy available from the arc. Numerous factors, including skin color, area of skin exposed, type of clothing have an effect on degree of injury. Proper clothing, work distances, and overcurrent protection can improve the chances of curable burns.

   - **Pressure Wave**. A high-energy arcing fault can produce a considerable pressure wave. Research has shown that a person 2 feet away from a 25,000 amp arc would experience a force of approximately 480 pounds on the front of their body. In addition, such a pressure wave can cause serious ear damage and memory loss due to mild concussions.

In some instances, the pressure wave may propel the victim away from the arc-blast, reducing the exposure to the thermal energy. However, such rapid movement could also cause serious physical injury.

- **Projectiles**. The pressure wave can propel relatively large objects over a considerable distance. In some cases, the pressure wave has sufficient force to snap the heads of 3/8-inch steel bolts and knock over ordinary construction walls.

  The high-energy arc also causes many of the copper and aluminum components in the electrical equipment to become molten. These “droplets” of molten metal can be propelled great distances by the pressure wave. Although these droplets cool rapidly, they can still be above temperatures capable of causing serious burns or igniting ordinary clothing at distances of 10 feet or more. In many cases, the burning effect is much worse than the injury from shrapnel effects of the droplets.

4. **Explosions**. Explosions occur when electricity provides a source of ignition for an explosive mixture in the atmosphere. Explosive atmospheres can result from the accumulation of flammable vapors or gases generated by nearby sources and processes. Ignition can be due to overheated conductors or equipment, or normal arcing (sparking) at switch contacts. OSHA standards, the National Electrical Code and related safety standards have precise requirements for electrical systems and equipment when applied in such areas.

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Practice good housekeeping around electrical equipment to reduce the risk of fires.

5. **Fires**. Electricity is one of the most common causes of fire both in the home and workplace. Defective or misused electrical equipment is a major cause, with high resistance connections being one of the primary sources of ignition. High resistance connections occur where wires are improperly spliced or connected to other components such as receptacle outlets and switches. This was the primary cause of fires associated with the use of aluminum wire in buildings during the 1960s and 1970s.

EFFECTS OF ELECTRIC SHOCK ON THE BODY

The effects of electric shock on the human body depend on several factors. The major factors are:

1. Current and Voltage
2. Resistance
3. Path through body
4. Duration of shock

The muscular structure of the body is also a factor in that people having less muscle tissue typically show similar effects at lesser current levels.

Current and Voltage

Although high voltage often produces massive destruction of tissue at contact locations, it is generally believed that the detrimental effects of electric shock are due to the current actually flowing through the body. Even though Ohm's law (I=V/R) applies, it is often difficult to correlate

voltage with damage to the body because of the large variations in contact resistance usually present in accidents. Any electrical device used on a house wiring circuit can, under certain conditions, transmit a fatal current. Although currents greater than 10 mA are capable of producing painful to severe shock, currents between 100 and 200 mA can be lethal. Table 1 provides the effects of electricity on the body for different current levels.

With increasing alternating current, the sensations of tingling give way to contractions of the muscles. The muscular contractions and accompanying sensations of heat increase as the current is increased. Sensations of pain develop, and voluntary control of the muscles that lie in the current pathway becomes increasingly difficult. As current approaches 15 mA, the victim cannot let go of the conductive surface being grasped. At this point, the individual is said to “freeze” the circuit. This is frequently referred to as the “let-go” threshold.

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THE LET-GO THRESHOLD:

If you receive an electric shock with a current magnitude between 13-15 mA, you lose control of your muscles and cannot separate yourself from the current source. The current magnitude where your body reacts in this way is called the let-go threshold.

Professor Charles F. Dalziel of the University of California ¾ Berkeley determined the let-go threshold in the late 1940s. He determined the threshold through statistical evaluation of experiments performed on human subjects.

Table 1
Effects of Current on the Body

CURRENT (milliamperes)	REACTION
Less than 1	Perception level. Faint tingling sensation.
1-8	Slight shock felt. Not painful but disturbing.
10-20	Painful shock. Loss of muscular control. Muscular "Freezing Level".
20-50	Extreme pain, breathing is difficult, severe muscular contractions. Individual cannot let go.
100 - 200	Ventricular fibrillation of the heart (The rhythmic pumping action of the heart ceases). Muscular contraction and nerve damage occur. Loss of consciousness, possible death.
200 +	Cardiac arrest, severe burns and possible death.

As current approaches 100 mA, ventricular fibrillation of the heart occurs. Ventricular fibrillation is defined as "very rapid uncoordinated contractions of the ventricles of the heart resulting in loss of synchronization between heartbeat and pulse beat." Once ventricular fibrillation occurs, it will continue and death will ensue within a few minutes. Use of a special device called a de-fibrillator is required to save the victim.

Heavy current flow can result in severe burns and heart paralysis. If shock is of short duration, the heart stops during current passage and usually re-starts normally on current interruption, improving the victim's chances for survival.

Resistance

Studies have shown that the electrical resistance of the human body varies with the amount of moisture on the skin, the pressure applied to the contact point, and the contact area.

The outer layer of skin, the epidermis, has very high resistance when dry. Wet conditions, a cut or other break in the skin will drastically reduce resistance.

Shock severity increases with an increase in pressure of contact. Also, the larger the contact area, the lower the resistance.

Whatever protection is offered by skin resistance decreases rapidly with increase in voltage. Higher voltages have the capability of "breaking down" the outer layers of the skin, thereby reducing the resistance.

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Path Through Body

The path the current takes through the body affects the degree of injury. A small current that passes from one extremity through the heart to the other extremity is capable of causing severe injury or electrocution. There have been many cases where an arm or leg was severely burned to the point of detachment when the extremity came in contact with electrical current and the current flowed through a portion of the limb before it went out into the other conductor without going through the trunk of the body. Had the current gone through the trunk of the body, the person would almost surely have been electrocuted.

A large number of serious electrical accidents in industry involve current flow from hands to feet. Such a path involves both the heart and the lungs. This type of shock can be fatal.

Duration of Shock

The duration of the shock has a great bearing on the final outcome. If the shock is of short duration, it may only be a painful experience for the person.

If the level of current flow reaches the approximate ventricular fibrillation threshold of 100 mA, a shock duration of a few seconds could be fatal. This is not much current when you consider that a small light duty portable electric drill draws about 30 times as much.

At relatively high currents, death is inevitable if the shock is of appreciable duration; however, if the shock is of short duration, and if the heart has not been damaged, a normal heartbeat pattern may resume after contact with the electrical current is interrupted.

SUMMARY OF EFFECTS

We can sum up the lethal effects of electric current as follows:

- Current flow greater than the "let go" threshold of an individual may cause a person to collapse, become unconscious and can result in death. The current flow would most often have to continue for longer than five seconds. Although it may not be possible to determine the exact cause of death with certainty, asphyxiation, or heart failure are the prime suspects.
- Current flow through the chest, neck, head, or major centers controlling respiration may result in a failure of the respiratory system. This is usually caused by a disruption of the nerve impulses between the respiratory control center and the respiratory muscles. Such a condition is dangerous since it is possible for the respiratory failure to continue even after the current flow has stopped.
- The most dangerous condition can occur when fairly small amounts of current flow through the heart area. Such current flow can cause ventricular fibrillation. This asynchronous movement of the heart causes the hearts' usual rhythmic pumping action to cease. Death results within minutes.
- When relatively large currents flow through the heart area, heart action may be stopped entirely. If the shock duration is short and no physical damage to the heart has occurred, the heart may begin rhythmic pumping automatically when the current ceases to flow.

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- Extensive tissue damage, including internal organ damage due to high temperatures, occurs when very large currents flow through major portions of the body.
- There are recorded cases of delayed death after a person has been revived following an electrical shock. This may occur within minutes, hours, or even days after the event has occurred. Several assumptions for such delayed effects are:
- Internal or unseen hemorrhaging
- Emotional or physical effects of shock
- Aggravation of a pre-existing condition

In many accidents, there is a combination of the above effects, or additional effects may develop after the initial accident, thus making an accurate diagnosis quite difficult.

The NHMFL is one of Tallahassee's largest electric consumers. During magnet research the laboratory has the ability to consume 40 megawatts of electrical energy each hour. In contrast, a medium sized family home uses about 60 kilowatts per day. Basically, there's a great amount of electrical power at NHMFL in a variety of locations. Some locations are more hazardous than others. This section is designed to inform employees of hazardous locations and equipment at NHMFL.

ALERTING TECHNIQUES AND BARRICADES

The following methods are used to warn and protect employees from hazards which could cause injury due to electric shock, burns, or failure of electric equipment parts:

1. *Safety signs and tags*. Safety signs, safety symbols, or accident prevention tags are used where necessary to warn employees about electrical hazards which may endanger them.
2. *Barricades*. Barricades are used in conjunction with safety signs where it is necessary to prevent or limit employee access to work areas exposing employees to uninsulated energized conductors or circuit parts. Barricades include locked rooms and areas, locked cabinets, and fences. (Conductive barricades may not be used where they might cause an electrical contact hazard.)
3. *Attendants*. If signs and barricades do not provide sufficient warning and protection from electrical hazards, an attendant shall be stationed to warn and protect employees.

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HIGH VOLTAGE LOCATIONS

OSHA has specific guidance concerning the accessibility of high voltage systems. High voltage systems are defined as those systems over 600 volts. The entrances to all buildings, rooms, or enclosures containing conductors operating at over 600 volts must be kept locked or must be under the observation of a qualified person at all times. A qualified person is an individual familiar with the construction, operation, and hazards associated with equipment. Qualified personnel include electricians and control room operators. NHMFL policy prohibits all non-qualified personnel from entering spaces containing equipment with a voltage rating of 600 volts or higher. Table 2 provides a list of qualified and non-qualified personnel by job title.

Figure 2 of the Electrical Area Controlled Access Procedure (Appendix B) provides a diagram of restricted high voltage areas at the laboratory. Table 3 provides the restricted high voltage areas at the laboratory. These areas are posted with high voltage signs. In addition, despite a voltage rating of less than 600 volts, the magnet power supplies (located in the OP/MD building mezzanine) and DC electric bus tunnels are off limits to non-qualified personnel.

LASERS

Lasers can contain significant levels of electricity in their capacitors if they are not properly discharged prior to lock-out. Electrocutions have occurred as a result of a capacitor being discharged during maintenance on lasers. The FSU Laser Safety

Manual provides detailed safety requirements for laser use.

Table 2
Non-Qualified and Qualified Personnel

NON-QUALIFIED PERSONNEL	
Assoc. Dir. University Relations and Publications	Visiting Scholar Scientist
Asst. Dir. Business Finance/Auxiliary Service	Accountants
Coord. of Admin. Services	Art Pub. Prod. Specialist
Coord. Computer System Control	Clerk-Typist
Coord. Educ. Media/Communication	Executive Secretary
Coord. Inform. Public Service	Office Assistant
Coord. of Accounting	Program Assistant
Coord. Research Services	Purchasing Agent
Assoc. Professors	Sr. Engineer Tech. Designer
Assoc. Program Dir/Assoc. Prof.	Sr. Clerk
Assoc. Scholar Scientist	Sr. Secretary
Asst. Scholar Scientist	Sr. Grants Specialist
Professor	Sr. Storekeeper/Rec. Clerk
Professor/Deputy Dir.	
Professor/Dir.	***Coord. Env. Health/Safety, except when accompanied by AUTHORIZED PERSONNEL and for OFFICIAL BUSINESS ONLY***
Professor/EMR Program	
Program Dir. & Professor	***No OPS Staff without the approval and supervision of the Senior Electrical Engineer.***
Scholar/Scientist	
Visiting Asst. Engineer	
Visiting Asst. Research	
Visiting Asst. Scholar/Scientist	
QUALIFIED PERSONNEL	
Eng. Tech./Designer	Sr. Eng. Tech. Designer
Asst. in Eng.	Sr. Eng.
Asst. in Res.	Sr. Res. Eng. Supp. Spec.
Res. Eng. Supp. Specialist	Sr. Research Eng.

Electrical hazards, while always present at the NHMFL, can be minimized. There are various ways of protecting from electrical hazards. These include:

- Locking and tagging equipment
- Guarding
- Grounding
- Mechanical devices
- Personal protective equipment
- Safe work practices
- Safe practices when working with portable equipment
- Proper use of electrical cords and plugs
- Safe practice when working at heights

This section describes each of these protective methods.

LOCKING AND TAGGING EQUIPMENT

The NHMFL has written Lockout / Tagout programs entitled "Safety Clearance Procedure (SP-1)" and "Safety Clearance and Administrative Documents (SP-2)." The purpose of this program is to isolate sources of electrical energy from equipment undergoing repair or maintenance. Personnel who employ lockout/tagout procedures are give specific training and must be approved to repair and maintain electrical equipment.

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WARNING: ***Even low voltage equipment, such as welding equipment, can present a severe shock hazard due to high electrical current levels.***

GUARDING

Live parts of electrical equipment operating at 50 volts or more must be guarded against accidental contact. Guarding of live parts may be accomplished by:

- Locating equipment in rooms, vaults, or enclosures accessible only to qualified personnel.
- Use of permanent, substantial partitions or screens to exclude unqualified persons.
- Locating equipment on a suitable balcony, gallery, or platform elevated and arranged to exclude unqualified personnel.
- Elevation of equipment 8 feet or more above the floor

In addition, entrances to rooms and other guarded locations containing exposed live parts must be marked with conspicuous warning signs forbidding unqualified persons to enter.

EQUIPMENT GROUNDING

By grounding a tool or electrical system, a low resistance path to the earth through a ground connection is created. When properly done, this path offers sufficiently low resistance and has sufficient current carrying capacity to prevent the buildup of voltages which may result in a dangerous shock. This does not guarantee that no one will receive a shock, be injured, or killed from grounded equipment. However, it substantially reduces the possibilities of such accidents. OSHA requires that all

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exposed non-current carrying metal parts of permanently installed equipment which may become energized be grounded when the equipment is:

- Within eight feet vertically and five feet horizontally of ground or grounded metal objects and subject to employee contact.
- Located in a wet or damp location and not isolated.
- Connected by cord and plug

MECHANICAL PROTECTION DEVICES

Mechanical protection devices are designed to shut off the flow of electricity in the event of a ground fault, overload, or short circuit in a wiring system. Fuses, circuit breakers, and ground fault circuit interrupters are three examples of mechanical protection devices

Fuses and circuit breakers monitor the amount of current that a circuit will carry. They automatically open or break the circuit when the amount of current flow becomes excessive and therefore unsafe. Fuses are designed to melt when too much current flows through them. Circuit breakers are designed to trip open the circuit. Fuses and circuit breakers are intended primarily for the protection of conductors and equipment. They prevent overheating of wires and components which might otherwise create hazards to operators.

The ground fault circuit interrupter, or GFCI, is designed to shut off electrical power within as little as 1/40th of a second. It works by comparing the amount of current going to an electrical device against the amount of

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high risk areas such as wet locations and construction sites. To ensure that a GFCI is operating properly, most GFCIs have a test feature. Test the GFCI regularly.

PERSONAL PROTECTIVE EQUIPMENT

OSHA requires that personnel working on electrical systems be provided with and use electrical protective equipment that is appropriate for the specific parts of the body to be protected for the work performed. The types of electrical safety equipment, protective apparel, and protective tools available are quite varied and include: rubber gloves, leather gauntlets, insulating sleeving, insulating blankets, face shields, safety glasses, linehoses, hot sticks, and voltage detectors.

SAFE WORK PRACTICES

Perhaps the single most successful defense against electrical accidents is the continuous exercising of good judgment or common sense. All personnel working at NHMFL should be thoroughly familiar with the safety procedures for their particular jobs. In general, however, the following safety rules must be followed at NHMFL:

- Personnel must operate electrical equipment in accordance with the manufacturer's recommendations. The safety instructions and operating procedures for all equipment shall be followed.

current returning from the device. The GFCI is used in

- Employees may not enter spaces containing exposed energized parts, unless illumination is provided to enable the employee to perform the work safely. Employees must not reach blindly into areas which may contain energized parts where lack of illumination or an obstruction precludes observation of the work to be performed.

- Unauthorized personnel shall not occupy areas around electrical switchgear, panel boards, or load centers.

- When working with electrical equipment, always work with a partner. The partner should observe the work from a safe distance and be trained in first aid/CPR.

- Where live parts present an electrical contact hazard, employees may not perform housekeeping duties at such close distances to the parts that there is a possibility of contact, unless adequate safeguards (such as insulating equipment or barriers) are provided. Electrically conductive cleaning materials may not be used in proximity to energized parts unless procedures are followed which will prevent electrical contact.

PORTABLE ELECTRIC EQUIPMENT SAFETY

Portable electrical equipment found at NHMFL may be laboratory-owned equipment or personal property. All laboratory-owned equipment must be inspected by the Facilities Maintenance Group prior to use. Personal portable electric equipment should not be used at the NHMFL.

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Inspection of laboratory-owned portable electrical equipment is necessary to ensure that the equipment is electrically safe and compatible with the installed power receptacles.

Types of Portable Electrical Equipment

Portable electrical equipment is normally classified according to the number of insulation barriers provided between the electrical conductors in the equipment and the user. Equipment which has two insulation barriers and does not have exposed metal parts are called double insulated. Double insulated tools provide reliable shock protection without third-wire grounding. Conventional electric tools have a single layer of functional insulation and are metal encased. Double insulation can be provided by encasing the entire tool, or at least the part of the tool which is handled, in a nonconductive material, such as plastic, which is also shatterproof. The National Electric Code permits double insulation on portable tools and appliances. Double-insulated tools that have been tested by Underwriter's Laboratories carry the square-in-square UL mark. Equipment with only two prongs on the electric plug and without the UL mark is not considered double insulated and is not approved for use at NHMFL.

Equipment that does not possess a two pronged plug and a UL mark must have a three prong electric plug. The third prong is used to ground exposed metal parts on the equipment.

Pre-Use Inspection of Portable Electric Equipment

Prior to using portable electrical equipment at the laboratory, the user must first perform a safety inspection. This inspection consists of looking for external defects and for evidence of possible internal damage. If there is a defect or evidence of damage that might expose an employee to injury, the defective or damaged equipment shall be removed from service, and no employee may use it until necessary repairs and tests render the equipment safe for use. The pre-use inspection will include inspection of the tool casing for cracks, dents, contamination (oil, moisture, dirt, corrosion). See Electric Cords, below, for inspection of cords and plugs.

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ELECTRICAL CORDS AND PLUGS

Electric Cords

Faulty or misused electric cords can present serious hazards. Basic electric cord safety practices include:

- Inspect cords regularly. Look for signs of stretching, insulation damage, and kinking. Don't use if these conditions are evident.
- Keep cords and cables clean and free from kinks. Kinking can damage both the cord's insulation and internal wire.
- Never carry a tool by its cord!
- When using tools which require a third wire ground use only three wire extension cords with three-pronged, grounding plugs and three hole electric outlets. Never cut off the grounding plug from a cord! If you see a cord with the grounding plug missing, have an electrician replace the plug.
- Pulling on electric cords can damage the cord insulation and cause electric sparks. Always remove the cord at the plug.

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- Extension cords may present a tripping hazard. Make sure that cords are not located in walking paths or a non-trip cover is placed over cords.
- Always use the correct extension cord for the job. An undersized cord can cause a drop in tool power and overheating. Check the manufacturer's recommendations for the wire gage (or thickness) and length of the cord based on your application.
- Portable electric equipment and flexible cords used in highly conductive work locations (such as those inundated with water or other conductive liquids), or in job locations where employees are likely to contact water or conductive liquids, shall be approved for those locations.
- Hands must be dry when plugging and unplugging flexible cords and cord- and plug-connected equipment, if energized equipment is involved.

Plugs and Receptacles

Electric plugs and receptacles are designed for different currents and voltages so that only matching plugs and receptacles will fit together, preventing a piece of equipment, a cord, and a power source with different voltage and current requirements to be plugged together. These standard configurations have been established by the National Electric Manufacturer's Association (NEMA).

In addition to proper selection of electric plugs, the electric plug must also be inspected properly. Inspection of plugs shall include signs of damaged or chafed insulation, overheating, prong condition, and installation of a ground plug if required.

WORKING AT HEIGHTS

When an unqualified person is working in an elevated position near overhead lines, the location shall be such that the person and the longest conductive object he or she may contact cannot come closer to any unguarded, energized overhead line than the following distances:

- For voltages to ground 50kV or below - 10 feet.
- For voltages to ground over 50kV - 10 feet plus 4 inches for every 10kV over 50kV.

In addition, portable ladders shall have non-conductive siderails if they are used where the employee or the ladder could contact exposed energized parts.

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SUMMARY

Each individual working in the NHMFL is at risk of being injured by electric shock. The magnitude of this risk is dependent on the employee's job tasks and work location(s). In order to maximize each individual's safety at the laboratory, each employee must be familiar with the NHMFL electrical distribution system, the hazards of electricity, and safety procedures and precautions.

During this training we described the basics of electricity, the hazards of electricity, the NHMFL electrical distribution system including high voltage areas, and electrical protection measures for minimizing electric hazards.

ATTACHMENT A

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Alternating Current - An electric current that reverses its direction periodically.

Amps (ampere) - Rate of flow of a current in a conductor of one coulomb per second. The amp is the standard unit for measuring the strength of an electric current.

Current - the flow of electric charge, or electrons

Cycle - One complete period of the reversal of an alternating current from positive to negative and back again.

Direct Current - An electric current flowing in one direction.

Electric Circuit - an unbroken path along which an electric current may flow. A simple circuit consists of a voltage source, such as a battery or a generator, whose terminals are connected to those of a circuit element, such as a resistor, through which current can flow.

Electric Field - a region at every point within which there is a force on an electric charge.

Electricity - The physical phenomena arising from the behavior of electrons and protons that is caused by the attraction of particles with opposite charges and the repulsion of particles with the same charge.

Electron - a type of elementary particle that, along with protons and neutrons, make up atoms and molecules. Electrons have a negative charge

Ground - A ground is a connection in an electrical circuit that leads to the earth, or to a large conducting object that is at zero volts with respect to the rest of the circuit. In every type of electrical system or device, accessible metal parts, such as frames, cases, and switches, are usually maintained at ground potential. If there is any defect or short circuit inside the tool, the current is drained from the metal frame through a ground wire and does not pass through the operator's body. If a ground is not used, the current “seeks” a ground. The operator’s body can serve as a grounding wire and the current will flow through the operator, causing injury.

Hertz (hz) - The international unit of frequency equal to one cycle per second.

Kilowatt-Hour - Unit of electrical energy or work, equal to the work done by one kilowatt acting for one hour.

Ohm's Law - Ohm's law states that the amount of current flowing in a circuit made up of only resistors is related to the voltage on the circuit and the total resistance of the circuit. The law is usually expressed by the formula V=IR, where I is the current in amperes, V is voltage (in volts), and R is the resistance in ohms.

Ohm - Unit of electrical resistance equal to the resistance of a circuit in which an electromotive force of one volt maintains a current of one ampere.

Power

Protons - a type of elementary particle that, along with electrons and neutrons, make up atoms and molecules. The proton has a positive charge

Resistance

Shock - Occurs when electric current flows through the body.

Transformer - An electrical device that transfers an alternating current or voltage from one electric circuit to another using electromagnetic induction.

Volt - a unit of electromotive force or difference in potential between two points in an electric field that requires one joule of energy to move a positive charge of one coulomb from the point of lower potential to the point of higher potential.

Voltage

Watt - Unit of electrical power equal to one joule per second or to the power developed in a circuit by a current of one ampere flowing through potential difference of one volt.

ATTACHMENT B

SAFETY PROCEDURE
SP-18

ELECTRICAL AREA CONTROLLED
ACCESS PROCEDURE